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CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

THE TRANSFER OF COMPUTER SOFTWARE IN CANMET

Three Case Histories

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RÉSUMÉ

Le présent rapport traite de la gestion du CANMET et du transfert de la technologie du logiciel mise au point au Ministère ou par impartition. L'étude porte en particulier sur trois ensembles de programmes élaborés au CANMET.

1. Le système CADD (Coding and Analysis of Drillhole Data) et le système GEM (Geostatistical Evaluation of Mines) mis au point par le Groupe d'évaluation des mines (GEM), Laboratoires de recherches minières.

2. Programme SPOC (Simulated Pro[illegible]sing of Ore and Coal) élaborés aux Laboratoires de traitemen[illegible]s minéraux; Laboratoires des sciences minérales (LSM).

3. La série CUPOLA des programmes (CUPOLA) de la fonderies du CANMET mise au point par les Laboratoires de recherche en métallurgie physique (LRMP).

Chaque ensemble a été élaboré dans le cadre d'un projet de recherche continu, soit comme outil de recherche pour atteindre les objectifs du projet (i.e., CADD et GEM) ou comme outil pour favoriser le transfert de technologie aux utilisateurs éventuels (i.e., CUPOLA et SPOC). Les programmes sont fondés sur des principes exploités antérieurement (en particulier, les principes portant sur les rapports et l'expression mathématique ou statistique) et sur des algorithmes récemment mis au point.

La dimensin approximative et la nature de la clientèle des programmes CUPOLA et SPOC et le besoin de technologie ont été établis avant l'élaboration de ces programmes. Quant aux systèmes CADD et GEM, l'intérêt qu'ils ont sucité chez les utilisateurs éventuels s'est manifesté après l'élaboration et l'application des programmes par le Groupe d'évaluation minière.

Dans tous les cas, le besoin d'élaborer des méthodes pour la présentation des nouvelles technologies à l'industrie était évident.

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SUMMARY

This report reviews CANMET's management and technology transfer of computer software, developed in-house or under contract. The case studies deal specifically with three CANMET-developed software packages:

1. Coding and Analysis of Drillhole Data (CADD) and Geostatistical Evaluation of Mines (GEM) systems developed by the Mine Evaluation Group (MEG), Mining Research Laboratories;

2. Simulated Processing of Ore and Coal (SPOC) programs developed by the Mineral Processing Laboratories; Mineral Sciences Laboratories (MSL).

3. Cupola Series of CANMET Foundry Software (CUPOLA) programs developed by the Physical Metallurgy Research Laboratories (PMRL);

Each package was developed as part of an ongoing research project, either as a research tool for use in meeting the objectives of the project (i.e., CADD and GEM) or as a tool to enhance the transfer of technology to potential users (i.e., CUPOLA and SPOC). The programs are based both on previously developed principles (mainly mathematical or statistical expressions and relationships) and on newly developed algorithms.

For the CUPOLA and SPOC programs, the approximate size and nature of the clientele were determined and the need for the technology was established prior to their initiation. For CADD and GEM, the interest of potential users became evident after the programs had been developed and applied by the Mine Evaluation Group.

In all cases, the need to develop methods for introducing new technology to industry was evident.

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INTRODUCTION

In the Spring of 1983, CANMET established a Task Force to study the transfer to outside users of computer software developed by CANMET scientists. This decision arose from an increasing number of problems related to intellectual property and possible patent protection and to handling and distribution procedures, including the user fee, licensing, machine compatibility, and other issues such as software support. It was believed that a Branch policy on the transfer of computer software was required, particularly since the use of computers can only accelerate.

A more basic issue underlying this task is to ensure that the transfer of technology from CANMET be conducted in a way to maximize user benefits. However, since each case is different, establishing guidelines for technology transfer is difficult.

Accordingly, it was decided to study in depth the actual genesis and transfer of three computer software packages, produced in three CANMET divisions; Mining Research Laboratories (MRL), Mineral Sciences Laboratories (MSL), and Physical Metallurgy Research Laboratories (PMRL). These case studies were researched and prepared by Peter Sutterlin under the direction of the co-chairman of the Task Force, J.André Potworowski. The three packages differ in size, complexity, user-friendliness, and application. SPOC and Cupola were developed on the basis of a perceived need in industry; the third, CADD/GEM, was intended primarily for internal use. However, since industry expressed a strong interest it was decided to make the technology available to outside users.

A number of common issues prevail in all three case studies, the first of which is the appreciation of the users' technological needs and level of computer literacy. A good understanding of client needs is important to successful technology transfer since it will guide not only the design of the software product but also its delivery.

A related element is the education and training of the user in the new computer approach; the size, degree of specialization, and level of computer sophistication of a firm will influence the education program required.

Another issue, yet to be fully resolved, is to identify proper mechanisms for handling and distributing the software to prospective users, including licensing, user fees, handling of inquiries, and maintenance of programs. A number of questions need to be answered:

1) Licensing: How should we protect CANMET software? While it is difficult at present to patent software, a number of mechanisms are evolving which would ensure some degree of protection of intellectual property in computer programs. One such mechanism is to use trade secrets; this requires that a secrecy agreement be signed between the software owner and the user. Should this approach be adopted?

2) User Fees: Some of the CANMET programs are estimated to be worth hundreds of thousands of dollars, if they were to be sold on the U.S. market. Given our mission, what would be a reasonable pricing policy?

3) User Inquiries and Maintenance: All CANMET programs require some interaction with users. This interaction, a necessary component of technology transfer, requires time and resources on the part of CANMET, which some claim is detrimental to the original goal of R&D and software development. What should be the proper level of effort dedicated to helping users, and for how long after the purchase/transfer should we continue to support the software? What should be the extent of CANMET's liability in ensuring adequate performance of these programs.

These are important issues for which a Branch policy needs to be established at the earliest possibility.

The case studies presented here should provide an insight into some of the realities of developing and delivering software. They should also provide a realistic basis for developing a Branch-wide policy for the distribution of software, as well as serve as a useful document to improve the effectiveness of transferring software to users.

Finally, these case studies would have been impossible without the substantial contributions of the three scientists involved in the development of the software packages; Ray Sabourin of MRL, now in EMR's Energy Sector, Dick Warda of PMRL, and Daniel Laguitton of MSL. To them, we express our fullest gratitude.

CODING AND ANALYSIS OF DRILLHOLE DATA (CADD) AND GEOSTATISTICAL EVALUATION OF MINES (GEM)

THE TECHNOLOGICAL PROBLEM

The feasibility of a mining operation is based on a mineral deposit's size, grade, and the market price of the product, which in turn determine the minimum ore grade, (i.e., the cut-off grade at a particular point in time), below which the deposit cannot be economically exploited.

A mineral deposit is a naturally occurring, three-dimensional ranging from a few cubic metres to thousands of cubic metres, the composition of which varies, sometimes erratically, from place to place. To assess this variability, holes are drilled into the deposit according to a predetermined pattern. The cores from these drillholes, (usually 1¼" in diameter), are analyzed (assayed) to determine those portions of the drillholes which have intersected-ore of a grade high enough to be economically mined. The sum total of these analyses constitute a sample of the variability and composition of the deposit which is used to predict the extent and nature of the orebody. In theory, the greater the number of drillholes analyzed (hence the number of samples), the more accurate the prediction. In practice, however, the validity of the prediction depends on both the suitability of the sampling design and the method used to establish the pattern of variability within the orebody on which reserve estimates are based.

Ore reserves have been estimated by classical techniques, using cross-sections, polygons, and other geometrical methods in order to define zones, and, ultimately, the volumes of economically-extractable ore. These techniques produce a graphical representation of the orebody and assume a basically linear variability relationship between drillholes in the deposit. However, evaluating an ore body is seldom, if ever, a straight-line equation. Better estimations sometimes tend to be those which incorporate statistical

techniques rather than those which rely solely on graphical methods. However, the number of variables and the calculations required to apply these statistical techniques make it impractical to use them operationally. Even when digital computers rapid enough to perform the calculations, became available, there was still no software to handle all the variables nor computer memories large enough to store the enormous amounts of data required. In the mid-1970's, significant advances in computer-hardware capability made it possible for groups like CANMET's Mine Evaluation Group to develop software to routinely apply the statistical techniques. The result is an additional method to estimate reserves based on accepted geostatistical principles coupled with those of conventional graphical methods, mining engineering, geology and mathematics.

PROJECT INFORMATION

The Mine Evaluation Group (MEG) of the Mining Research Laboratories (MRL) is part of the departmental Uranium Resource Appraisal Group (URAG) which, in includes personnel from CANMET, the Geological Survey of Canada (GSC), and the Uranium and Nuclear Energy Branch of the Conservation and Non-Petroleum Sector. Each year, MRL's Mine Evaluation Group makes a complete internal report to URAG on reasonably-assured uranium resources. URAG objectives are to determine the uranium resources in Canada (reasonably assured as well as the estimated additional) and to publish summary results every two years. The latest report "Uranium in Canada - 1980 assessment of supply and requirements" was published in 1981.

MEG, as a component of the Uranium Resource Assessment Project, is responsible for determining the reasonably assured (measured and indicated) uranium resources for Canada. It also assesses for GSC personnel the associated inferred resources. This project began in 1974 under Emil Dubnie. In 1975, a geologist, A. Fustos, was assigned to the project and in August of the same year, a geostatistician, R. Sabourin, was hired. In 1976 the present head,

R.J.R. Welwood, was appointed and a programmer, J.F. Folta, and two geologists, and one mining engineer were hired. Folta left the group in 1977 and Russell Boyle was hired soon after as a computer programmer.

Initially, no project element was specifically defined for the development of computer programs. The primary task was to assess the reasonably-assured uranium resources, using data supplied by exploration and mining companies. It was obvious from the beginning that a large amount of data would be gathered and many evaluations would be made. These evaluations, done manually, are time consuming. Therefore, it was decided to develop computer programs to help MEG's geologists conduct reserve evaluations. MEG also intended to use geostatistical techniques as one of the assessment methods. Subsequently, programs were developed to support this activity.

SOFTWARE

It is important to note that various methods of reserve assessment are justified depending on the characteristics of each mineral deposit. The 12 CADD programs, (MEG 401, 402 403, 405, 410, 411, 420, 1000, 1010, 1500, 1600, 1650), store and edit drillhole data, compute some derived values and prepare input files for the GEM System, which consists of 15 programs, (MEG 100, 2010, 3000, 2040, 2050, 2055, 2100, 2200, 2250, 2275, 2300, 2350*, 2400, 2500*, 2560). If desired, CADD programs may be used independently of GEM programs and vice versa.

* These programs are not accessible to the public. They can be used only by EMR employees.

In conducting required mineral-deposit assessments, MEG's primary objective is to calculate independent results based on primary drillhole data rather than on interpreted company data. Since 1981, MEG has been calculating economical intersections by computer from such raw data. The GEM programs determine economically-recoverable mineralized ore zones along drillholes, compute trends and variograms which describe the variability of the mineralization within the orebody, and then estimate block-grade values based on a geostatistical technique known as "kriging". The basic assumptions for such assessments include statistically normal distribution of mineral values.

The algorithms, particularly those embodied in the GEM programs, are complex. The programs are original, except for two, where the basic logical procedure was developed at the École Polytechnique in Montreal. However, extensive additions and modifications were made to these two programs in order to meet the specific needs of the group.

The software is not, at this time, computer independent. The program development was done using COBOL and FORTRAN IV on the CDC CYBER computer operated by EMR. Several special features of the FORTRAN Compiler were utilized to optimize the execution of the programs. To be utilized on other computers, the programs would have to be revised to eliminate the CDC-specific FORTRAN statements.

The CADD and GEM programs are executed in remote batch, i.e., using an on-site terminal station connected by telephone line to the CDC CYBER, with the output produced either at the Computer Science Centre and forwarded to MRL or directly on MRL's printers at Bells Corners. The programs cannot be run by an uninitiated user. The programs to be executed and the commands required assume an understanding of both the CADD and GEM programs and the CDC CYBER command language. Interpretation of the output requires a knowledge of the mathematical and geostatistical techniques. However, there is no requirement that the user know how to program. It would be possible to rewrite the program in an

interactive mode in which the terminal operator would only have to respond to a series of question-prompts. This would make execution of the programs from a remote terminal much easier and user-friendly.

The programs require from 70K to 300K (octal) words of internal memory to execute, depending on the size of the data matrix. The average matrix requires 100K (octal) words which is roughly equivalent to 32 768 (decimal) bytes and beyond the present capability of most microcomputers. Although some microcomputers are now being marketed, with up to 1024K bytes of internal random access memory (RAM), e.g. APPLE Lisa, it is apparent that, for the immediate future, CADD and GEM may still require access to a mainframe computer such as the CDC CYBER. However, microcomputer technology advancement eventually will make it difficult to resist a conversion of the CADD and GEM systems for use with microcomputers.

The CADD and GEM programs are documented in a series containing 27 reports: ERP/MRL 83-1 (TR), ERP/MRL 82-63 (TR), ERP/MRL 82-89 through ERP/MRL 82-113 (TR). These reports are in the form of user manuals but do not include the program listings, i.e. the FORTRAN source code. The form of documentation was designed by MEG but patterned after an IBM form of documentation.

TECHNOLOGY TRANSFER

The CADD and GEM systems were developed because there were no computer programs commercially available to do the reserve estimations adequately. At the time, public release of the software was not contemplated. The objective of the developers was to devise a computer-based method for storing, retrieving and manipulating the data needed to estimate ore reserves using geostatistical methods and to calculate these reserves. Support of these programs was supplied on an ongoing basis by MEG's computer programmer and geostatistician. Even though the emphasis has been on the assessment of uranium reserves, the

systems can be applied to other base metal mineral deposits, as well as sedimentary iron ore formations and coal deposits.

MEG did not seek advice or systematically survey potential clients because, in terms of the original objectives, there was no need. Nevertheless, uranium exploration and mining companies are obvious clients. Potential clients include other exploration and mining companies, consultants, other government departments and agencies, teachers in universities and foreign organizations. Since release of the programs, based on a list of industry and other contacts, 75 potential users of the software were identified and inquiries were received from 35. Most of those who inquired are computer-oriented and have access to mainframe computers. Unlike the other two cases in this study, the software for this project was released to the public specifically as a result of industry interest.

The programs and their availability have been publicized through the Open File list, distributed by the Technology Information Division (TID), and a paper presented at the 1982 CIM annual meeting in Quebec City. Future advertisement will be in the form of a news brief and possibly the publication of Division Report ERP/MRL 83-1 (TR) in the CIM Bulletin as well as an article in GEOS. All potential clients in Canada who are in contact with CIM will learn of the software availability.

When an inquiry is received, a requisition form for the software is sent with Report ERP/MRL 83-1 (TR). TID forwards to the requestor a magnetic tape containing the source FORTRAN code, a set of test data, a coding guide (ERP/MRL 82-63) and coding sheets, and 25 user manual reports. The fee is $500 (Canadian) for the package. Arrangements were made with Supply and Services Canada, to delegate their authority for distribution to CANMET.

MEG staff, in their regular internal use of these systems for mineral reserve assessments, may be required to make changes periodically in the documentation and logical procedure of the programs.

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TECHNICAL DATA

Name of Software	:	Coding and Analysis of Drillhole Data (CADD) Geostatistical Evaluation of Mines (GEM).
Function of Software:		Estimation of ore reserves using geostatistical methods; storage and retrieval of drillhole data.
Computer	:	CDC CYBER 730
Operating System	:	NOS/BE
Word Length	:	60-BIT
Memory Requirements	:	300K (OCTAL) Words
Programming Language:		FORTRAN, COBOL
Access Mode	:	Remote Batch

SIMULATED PROCESSING OF ORE AND COAL (SPOC)

THE TECHNOLOGICAL PROBLEM

After it is received from the mine or quarry, an ore must normally be processed before it acquires a usable form. The purpose of mineral processing (ore dressing or beneficiation) is to regulate the size of the desired product and to remove unwanted constituents (gangue) so that the quality, purity, or assay grade of the desired constituents (concentrate) can be improved.

Ore dressing and beneficiation are effected by crushing, grinding, dense media (heavy liquid) separation, gravity separation with cones, jigs and tables, flume separation, magnetic separation, pressure and/or heat treatment, and froth flotation. In most instances, these processes are carried out in mills located at or near the source of the ore. Each mill is specifically designed to process a given volume of ore (tonnes per day) to produce a desired product in the most cost-effective way while minimizing the environmental impact of the milling operation.

Up to 30 different steps can be included in a milling circuit. Each involves a process which in turn is based on the principles of mineralogy, physics, chemistry and engineering. A complete milling circuit is, therefore, scientifically and technologically very complex. Solutions to problems which occur normally require expertise in a number of disciplines.

Any change, such as variation in the nature of the ore, abnormal wear of machinery, a change in the concentration or quality of reagent, a failure of the monitoring instrumentation, etc., can cause a significant decrease in the mill throughput. Shutting down a milling operation to correct a problem in the milling circuit is extremely costly. Before this step is taken, the mill operator must be reasonably certain that the cause has been diagnosed correctly. Due to the complexity of most mill circuits, the problem

may be difficult to pinpoint, and even when the cause is identified, the expertise required to resolve the problem is not always available, at least not on-site.

The SPOC programs are designed to overcome these difficulties by permitting the mill operator to use a computer to simulate a specific mill circuit. The scientific and technological principles are embodied in the programs and can therefore be readily applied. In addition, there is no need to interrupt the operation to correct a problem until the probable cause of the problem has been identified off-line by the simulation procedure.

PROJECT INFORMATION

The SPOC project was initiated in 1980 under CANMET's Mineral Research Program by the Mineral Sciences Laboratories (MSL). The project has been under the direction of D. Laguitton and L. Sirois. The objectives of the project are to promote the use of computers for process evaluation and process optimization in the mineral and coal processing industries by developing and transferring documented software. The software is user-friendly and aids in process-related computation and simulation.

The need to develop software of the type embodied in the SPOC programs became evident during visits across Canada to many mineral processing plants. Few plants were utilizing all the available technological tools to maximize efficiency. It was apparent that the only practical way to transfer a multidisciplinary methodology to processing mills with a reasonable degree of ease was through readily usable computer software. Barring this, the methodology would have had to be transferred on the basis of the complete spectrum of specialties upon which mineral processing technology is based, e.g. process theory, mathematics, computer programming, process engineering.

SOFTWARE

The SPOC software is divided into several elements. Each addresses a specific aspect of the milling process, from the processing of sampling data and process inventory, to flowsheet simulation and process optimization. One element is used in designing a sampling assessment experiment. This leads to a better understanding of the significance of various kinds of acquired and/or hypothetical data which can assist in designing a sampling experiment, and ultimately, to establish best estimates of circuit flowrates. Another element includes the material balance computations. The program adjusts experimental data in such a way that all material balance constraints are met. This is done by distributing the experimental errors according to a realistic error model to which probabilities can be assigned. A third element is used to calibrate the simulation model. The output of a mill circuit can be expressed as a function consisting of a number of variables which must be evaluated objectively for the function to reflect actual operating conditions. This is the basis of the model calibration methodology. Another program simulates units and entire circuits to aid in process design and predict the mass balance of the circuit. Finally, a program is used to generate graphic output, design flowsheets, etc. Complexity of the algorithms ranges from trivial to elaborate.

Previously, and still prevalent to a large extent, sampling in a mill was not always done on a scientific basis. Material balance calculations were done by hand using a simplifying algorithm which did not take into account the experimental errors. Model calibration was seldom done. All of these methods suffered from the inherent limitations of manual calculations. There has been no new process theory as such developed. Rather, the novelty of the SPOC approach is the link between the different phases of the project which can now be made using the computer programs. There had been algorithms incorporated in previously written programs, but different programming languages had been used and the programs were not coordinated into a system.

The SPOC programs were written to run on the CDC CYBER computer, therefore they are not completely machine independent. However, modification of the programs for execution on other computers should not be too difficult since as many machine-dependent features as possible were avoided, and such occurences are identified in the documentation. The programs are run in an interactive mode on the CDC CYBER machine. Most of the software requires only a simple Visual Display Unit (VDU) terminal, although some programs require a graphics terminal and corresponding software library routines.

The design of the software is such that the programs can be executed by a relatively uninitiated user. However, in some of the programs user friendliness cannot substitute for engineering experience and judgement. For example, to perform a material balance calculation, whether or not a computer is used, an understanding of the detailed flowsheet of the plant, the quality of the samples, and the notion of statistical confidence intervals are required. These notions are explained in the SPOC manuals.

The software is for off-line application, i.e., the SPOC system is not intended for on-line process control, but rather to simulate plant processes and act as an aid in designing mill circuits and establishing a control strategy.

As written, the SPOC programs require a mainframe computer with an interactive time-sharing operating system. The programs themselves require up to 63K bytes of internal memory in addition to the operating system and data array requirements. A FORTRAN compiler is required. The programs presently make full use of the CDC CYBER's 60-bit word length.

TECHNOLOGY TRANSFER

One of MSL's most important objectives is to make certain that the widest possible use is made of the SPOC system. To ensure this, as well as guide the SPOC development, contacts were maintained with potential users through various channels over the past two years. The SPOC Steering Committee, a small group of representatives from the mineral and coal industry, acts as a "board of directors" to keep the project in line with industrial needs and ensure continuation along the initial project outline. The SPOC mailing list contains more than 80 organizations which are contacted annually to solicit comments on the progress of the project. Much of the work has been done under contract. However, the project planning and administration is the responsibility of CANMET. Three organizations have acquired the SPOC system (excluding the executive program). Seventy organizations have acquired the material balance calculation program.

The SPOC project was presented at conferences of the CIM and the Canadian Mineral Processors Association. Three specialized workshops were held. Two workshops were cancelled because of restrictive travel budgets of potential attendees. Summer students were introduced to the technology. Letters and manuals were sent to many potential users and the SPOC reports are included in CANMET's File list. Influential and knowledgeable representatives from major companies were enrolled to serve on the steering committee. In this way, everyone with a potential use for the SPOC system is at least aware of its existence and that the project is ongoing.

The SPOC system can be accessed in two ways. Some programs, in source code form, are already available on magnetic tape along with the user manuals from CANMET, through the Computer Science Centre on a cost-recovery basis. The EMR CYBER computer can also be accessed directly for trials by any valid Computer Science Centre account holder and the user is billed directly by the centre based on a standard fee schedule.

There is no mechanism to provide software support. MSL seeks feedback to enhance the software to suit the project's objectives. This is considered to be an integral part of the R & D process. Also, in practice, the maintenance of positive contacts requires a certain amount of assistance in solving problems, especially in the early stages of the transfer process. This is because the objective is not only to transfer a tool (software) but in this case, an entire methodology that will grow inside the industrial R & D sector. Computer-based methodology ultimately requires computer maintenance (both hardware and software) which tends to require adjustments in staff responsibilities. However, software support on an ongoing basis after the R & D process (including the transfer process) has been completed is not deemed appropriate.

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TECHNICAL DATA

Name of Software : Simulated Processing of Ore and Coal (SPOC).

Function of Software: Automation of mineral process inventory by material balance calculations, sampling methodology, simulation of process units.

Computer : CDC CYBER 730

Operating System : NOS/BE

Word Length : 60-BIT

Memory Requirements : 77K (OCTAL) Words

Programming Language: FORTRAN

Access Mode : Remote Interactive

CUPOLA MELTING EFFICIENCY (CUPOLA)

THE TECHNOLOGICAL PROBLEM

A cupola furnace is best described as a "chimney furnace" ranging from 60 cm to 350 cm in diameter. Most irons today which are used to make ductile or grey iron castings are melted in cupola furnaces. Modern cupola melting goes back to the beginning of the last century when it was found that cupola-melted liquid irons were well suited for castings of all types.

Cupola is a collective name, for there are more differences than similarities among individual cupola furnaces. In addition, two cupola furnaces of identical design and operating under identical conditions can produce irons of differing chemical compositions as well as differing physical properties. (Moreover, the quality of iron from any given unit tends to vary with time.) This is because the melting characteristics (run) of a cupola furnace, once it is charged with metal, coke, and flux (usually limestone) are influenced by many variables, such as;
bed height, blast air quantity, blast air moisture, blast air moisture content, coke quality and sizing, furnace construction and lining, metallic charge, quality and quantity of non-metallic charge components, slag composition, slagging.

The objective of foundry melting operations is to minimize the direct cost of converting a given amount of metallic charge into an equal amount of liquid iron which has the desired chemical composition and physical properties. This is really a question of optimization by considering all variables and their relationship to each other to determine values which will result in the most efficient operation. The computations involved in such a procedure are voluminous and formidable, and require expertise in a number of related, yet distinct, disciplines. The required technical resources are not normally available to the average foundry operator, therefore, most foundries are operating at less than optimal efficiency. This increases costs and decreases ability to compete in world markets.

PROJECT INFORMATION

The development of the CANMET CUPOLA software package is an element of the cupola melting efficiency program. The objective is to encourage the application of microcomputers in Canadian foundries by using them as a medium in the technology transfer process in providing technical assistance to the industry.

The design, operating practices and resultant melting efficiencies of 30 representative Canadian cupola operations were assessed by a PMRL task force during a coast-to-coast survey completed in 1980. This survey, based on comprehensive in-plant tests, resulted in the acquisition of a large volume of data. The accumulated data, resulting from 75 days of industrial testing, were analyzed a comprehensive bibliography of cupola-related literature was published, and consultations with foundry industry experts were held. The result was the compilation of a significant quantity of information on both new and old technology related to cupola design and operating practice, and the identification of significant deficiencies in both areas. The need for technological improvement was thereby established. It was concluded that the use of microcomputers with specially designed technical software could enhance the transfer process. The programs incorporate the required multidisciplinary technological principles and data in computer programs which are easy to use. This eliminates most barriers present to the application of new technology to improve cupola efficiency.

SOFTWARE

The CANMET CUPOLA software package consists of four programs described below. Three additional programs — cupola troubleshooting; cupola melting cost analysis; statistical process control -- are being developed and tested and will be added later.

1) Cupola Melting Efficiency Program

The most commonly used measure of melting efficiency has been the metal-to-coke ratio in the cupola charge. This measure has been shown to be inaccurate and misleading. Ideally a heat balance calculation should be used to determine both thermal and melting efficiencies and to identify major heat losses. For many foundry operators, the cupola heat balance calculation is not only tedious but formidable. The cupola melting efficiency program implemented on the microcomputer makes this an easy 5-min. exercise. The foundryman only has to load the diskette into the microcomputer and respond to prompts which request certain data. In addition to the actual calculation, the operator receives continual feedback of data from the program bringing important aspects of the cupola operation to his attention during program execution.

2) Cupola Charge Calculation Program

Cupola melting may result in significant changes in composition of the metallic charge as it is melted and superheated in the furnace. The extent of these changes depends on both the original charge composition and the cupola operating practice and makes prediction of the properties of the metal at the cupola spout difficult. This program offers a simple and rapid solution. The required calculations are performed and the properties of the metal at the spout are estimated, based on data requested by the program and supplied by the operator. The lengthy calculations and somewhat complicated relationships among the variables which have to be considered are submerged as algorithms in the program.

3) Cupola Acid Slag Analysis Program

The primary goal in fluxing practice is to produce a fluid, manageable slag. The quantity and acidity of melting slags in cupolas vary greatly as a result of different degrees of charge cleanliness, refractory materials, and cupola operating practices.

All of these variables must be considered before the correct amount of limestone or other flux can be specified. This program considers all variables and calculates the correct amount of limestone addition to produce a slag of the required composition.

4) **International Cast Iron Specification Program**

This program includes a file containing specifications from all major industrialized countries for grey, ductile and malleable iron. When an operator types into the microcomputer any part of a specification such as grade, microstructure or other property of a cast iron, the program will search the file and display the complete specification for all irons which match the input data.

The programs are designed to be executed in interactive mode using an Apple II+ or a TRS-80-11 microcomputer with a minimum of 64K bytes of internal Random Access Memory (RAM) and a diskette drive. To quote Warda and Whiting (1982) "Computing knowledge required to operate the programs is restricted to the ability to turn on the computer, insert the (autostart) diskette and operate the keyboard in response to instructions from the program". However, interpretation of the outputs does require knowledge of foundry practice.

The programs are written in BASIC programming language and are therefore relatively machine independent. However, due to operating systems incompatibilities, some modification would be required before the program could be executed on other than Apple or TRS-80 microcomputers.

Since the Cupola programs are interactive, and the instructions to the user are embedded in the programs, documentation in conventional terms is not essential. However, the theoretical background for the algorithms is included in various published reports and articles.

TECHNOLOGY TRANSFER

The software was developed for foundries which operate cupola furnaces. There are 78 such foundries in Canada. Of these, it is estimated that 20 will acquire and use the cupola software. Also there are 900 potential clients in the United States and 300 in Europe. The above-mentioned survey established the need for the technology, and led directly to the identification of software (along with the microcomputer) as the most effective medium of transfer.

The technology embedded in the Cupola programs is not normally used by the average foundry operator as long as the calculations required have to be performed manually. However, implementation of the technology on a microcomputer using user-friendly software has proven to be an acceptable methodology as far as the industry is concerned. Many foundries either already have, or plan to acquire, personal or micro computers to aid in accounting, financial, and office management applications. These machines are now affordable to even the smallest operators. Therefore, the potential clientele who are not already computer-oriented will probably become so in the near future.

To date, PMRL has held 5 regional seminars designed to demonstrate the software and to give potential users some hands-on experience with both the software and the microcomputer. Roughly 160 persons have attended the workshops - between 15 and 35 each session. The advantage of designing the system for interactive use on a microcomputer has become obvious during the workshops. Since the potential clientele are unlikely to go beyond the microcomputer insofar as computing hardware is concerned, being able to travel with a microcomputer and demonstrate the system in this manner tends to make the entire technology (not only the computer technology) much more acceptable to the user.

The actual transfer of the Cupola software is being achieved in conjunction with Canada Patents and Development Limited (CPDL). PMRL will act as the technical "salesperson" while CPDL will act as the marketer and licensor of the programs. Royalty rights, which in Canada can be retained by the authors of computer programs, have been waived voluntarily by the authors to avoid any suggestion of conflict of interest. Royalty rights have, however, been retained for the United States where CPDL is licensing the software to the American Foundryman's Society to market and distribute through their recently established Software Clearing House. Additional marketing will be done through published reports and of announcements included in CANMET's Open File list.

No formal mechanism has been established for systems support. As long as the programs are still in the developmental stage, program deficiencies and weaknesses will be corrected and users will be informed. Other considerations which revolve around the questions of hardware, and operating systems incompatibilities, and the level of sophistication of the users have yet to be addressed.

CUPOLA MELTING EFFICIENCY REFERENCES AND DOCUMENTATION

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TECHNICAL DATA

Name of Software : Cupola Melting Efficiency (CUPOLA)

Function of Software: Penetration of cupola furnace efficiency; charge parameters; calculations; analysis of sand system; gating and risering calculations.

Computer : Apple II +; TRS-80-11

Operating System :

Word Length : 8-BIT

Memory Requirements : 64K-BYTES

Programming Language: Basic

Access Mode : Direct Interactive

Appendix A

SUMMARY TABLE

TABLE 1 - SUMMARY

	CADD & GEM	CUPOLA	SPOC
Purpose for which the project was initiated	To provide an alternative method to assist MEG in assessing the reasonably-assured, (measured and indicated), uranium reserves for Canada.	To improve the technological capability of the Canadian foundry industry; to assist PMRL scientists in transferring technologies to foundry operators.	To develop a tool for the evaluation and optimization of mill circuit operation and design in the ore and coal processing industries; to promote the use of computers in these industries.
Basis for the establishment of the need for the project	The internal requirements of MEG as part of the departmental Uranium Resource Assessment Group (URAG).	A coast-to-coast survey of Canadian foundry operations; 75 days of industrial testing.	Visits to many mills across Canada which indicated that only a few were using available technologies maximize efficiency.
Basis for the need to develop computer software	The amount of raw data to be stored and the number and complexity of calculations required for the geostatistical methods preclude manual application of the methods. Computer-aided techniques are mandatory.	The calculations required to derive the parameters for more efficient operation of cupola furnaces are tedious and formidable if done manually. Consequently, they are seldom performed in most foundry operations.	Design and optimization of milling circuits require background in a number of disciplines. The most practical way to link the different phases of mill operation is to embody the multi-disciplinary principles into computer programs.
Target clientele at initiation of project	MEG and URAG.	Canadian foundries operating cupola furnaces, (about 78).	Canadian milling industry (about 256 operating mills).
Potential clientele	Companies mining stratiform ore deposits, including uranium and base metal deposits, sedimentary iron formations and coal measures.	In addition to the Canadian clientele, there are 900 cupola operators in the USA and 300 in Europe.	Up to one third of the Canadian mills could use the software - as well as foreign operators.

TABLE 1 (Cont'd)

	CADD & GEM	CUPOLA	SPOC
Present users	Selected firms and industries.	Selected firms and industries.	70 operators have acquired the material balance programs; 3 firms have acquired the entire system, excluding the executive program.
Computer requirements	Programs have been developed for execution on EMR's CDC CYBER mainframe computer.	Programs have been developed for execution on an APPLE II+ or a TRS-80 microcomputer.	Programs have been developed for execution on EMR's CDC CYBER mainframe computer.
Programming language	FORTRAN and COBOL. Algorithms are generally complex.	BASIC. Algorithms range from simple to quite complex.	FORTRAN. Algorithms range from trivial to complex.
Execution mode	Remote batch.	Interactive.	Remote interactive.
Degree of ease of use of the programs, i.e., user-friendliness	Moderately difficult.	Very easy.	Moderately easy.
Expertise required to use the software	An understanding of the CYBER command language and an appreciation of the geostatistical techniques involved.	An understanding of foundry operations.	An understanding of milling practice and some facility in SPOC command language.
Degree of machine independence of the software	The programs use some CDC CYBER-specific features and would have to undergo fairly extensive modification for use on other computers.	The programs should be executable on any microcomputer with an APPLE or TRS-compatible operating system.	As many CDC CYBER-specific features as possible have been avoided, but full use is made of the CYBER 60-bit word length; some modification would be required for other computers.

TABLE 1 (Cont'd)

	CADD & GEM	CUPOLA	SPOC
Awareness and creation	Availability of programs was publicized in CANMET's Open File list and a paper presented at the 1982 CIM annual meeting. A news brief, an article in GEOS, and publication of report ERP/MRL 83-1 ( ) are planned.	Publication of reports and articles.	Presentations at CIM and Canadian Mineral Processors Association meetings; letters and manuals to potential users; CANMET's Open File list;
Technology transfer	CIM presentation, selected industry responses.	Five regional seminars and workshops, presentation of papers at meetings.	Three specialized workshops were held.
Method of distribution of the software	Acquisition of the systems is through CANMET's Technology Information Division for a fee of $500 Canadian. Supply and Services Canada have delegated the distribution function which they would normally handle.	Canadian Patents and Development Corporation (CPDL) will act as licensor and marketer of the CUPOLA software. One of the licensees is the American Foundryman's Society which will market the software in the USA. A fee schedule is to be determined.	Programs in source code form are available on magnetic tape from CANMET through the EMR Computer Science Centre on a cost recovery basis. Direct access to the EMR computer on a trial basis can be arranged. A standard fee schedule is to be established.
Intellectual Property	No protection.	No protection.	No protection.